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James

Experiments on Preservation and Ripening
of Fruits

EXPERIMENTS ON PRESERVATION AND RIPENING OF FRUITS

BY

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Pavy

THESIS

FOR THE

DEGREE OF BACHELOR OF SCIENCE

IN

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The experimental work on the Preservation and Ripening of Fruits reported in this Thesis was carried on under the direction of Dr. F. W. Muncie and Prof. E. W. Bailey.

The planning and carrying on of the laboratory work was under the supervision of Dr. Muncie.

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EXPERIMENTS ON PRESERVATION AND RIPENING OF FRUITS

The following work was carried on on peaches and apples in order to determine, if possible, the chemical and physiological effects of various treatments upon the fruits.

The experimental work may be logically divided into four sections: SECTION ONE - THE COATING AND TREATMENT OF PEACHES WITH VARIOUS MATERIALS, UNDER VARYING CONDITIONS AND THE EFFECT UPON THE DECOMPOSITION OF THE PEACHES. In this work it was hope to find some method by which ripe peaches could be prevented from"breaking down"so soon after picking, thus prolonging the marketing of the peach crop. SECTION TWO - RESPIRATION OF RIPE APPLES IN AN ATMOSPHERE OF OXYGEN. In this work the aim was to determine the effect of oxygen upon the rate of respiration of apples and to find whether supplying an abundance of O_2 by force ventilation of storage plants or refrigerator cars with air, would counteract the value of forced ventilation as a preventative of "ice scald" by increasing the breaking down of the fruits. SECTION THREE; COLOR AND IT'S CORRELATION WITH THE ACIDITY OF AN APPLE. Is there a correlation between the percent of acidity in the meat of an apple and the intensity of color of the epidermis? And does the lack of color developement in apples, within a variety, correspond with the difference in the acidity of the meat as compared with a highly colored apple of the same variety? SECTION FOUR -

EFFECT OF DRYING OR EVAPORATION UPON THE ACIDITY OF THE FLESH AND THE COLOR OF THE EPIDERMIS OF THE APPLE. The aim was to preserve both the color of the epidermis and the color of the meat during the process of drying and also to find what effect drying had on the acidity of the apple.

I - THE COATING OF PEACHES WITH DIFFERENT MATERIALS UNDER VARYING CONDITIONS AND THE EFFECT UPON THE DECOMPOSITION

The following work was done with the hope of getting some suggestions for further and more detailed work along the line of retarding or inhibiting, the sudden "breaking down" of ripe peaches. If some mechanical or chemical means could be developed which would make the above possible, it would solve many difficult problems which confront the grower and commission man today. The fruit would be left on the trees until fully developed which would add to their flavor, size, color and beauty, thus eliminating the packing of fruit green and hard when they are to be held any length of time.

Due to the time that the work was taken up it was impossible to obtain peaches except from the state of New York which had been in cold storage for some time. Only the following brief data was obtainable on the Elbertas used: The peaches were picked about September 15, 1916, and put in cold storage at Lockport, N. Y. On Oct. 15, they were shipped to Chicago and stored again. Oct. 18, three bushels were obtained from W. H. J. Cavanaugh (Commission man) Chicago, being shipped in a refrigerator car to the University. In all, these peaches had been off the trees for over four weeks, had been in different storage houses and shipped some seven

hundred miles.

The peaches were of medium size, uniform, and put up in bushel baskets without tiering or center post. They were hard and showed no signs of decomposition or fungous growths.

1 - PEACHES IMMERSED IN OLIVE OIL.

A. OCT. 19 Some of the peaches were coated with vaseline and immersed in olive oil. The container was left on the laboratory table at room temperature (22° C). OCT. 20 Bubbles of CO_2 were being slowly given off. OCT. 23 Rate of bubbling increased. OCT. 30 The epidermis of the peaches had turned brown, except where they touched the container. NOV. 8 The entire surface of the peaches was dark brown in color. The meat was still hard and firm but the oil had penitrated thru the entire peach in every case. NOV. 16 Marked decomposition had set in and the meat was soft and mushy. Fermentation was also setting in.Due to the penitration of the oil into the fruit, it would be impossible to use oils beneficially in checking the decomposition of peaches.

2 - PARAFFIN AS A COATING TO PREVENT CONTACT WITH O_2 OF THE AIR.

Next a series was run using paraffin. The different melting points were obtained by mixing, in different proportions, liquid and solid paraffin.

A. OCT. 19 Peaches were placed in a fruit jar with some solid paraffin, the jar was sealed, the air pumped out and heat was

applied to melt the paraffin, the peaches were coated with the warm paraffin by rolling the jar. The melting point of the paraffin was about 34° C. The jar was kept in the ice box with ice in the same apartment as the peaches.

Dec. 18 . There was no apparent decomposition of the skeleton as the flesh was firm and the color of the meat and epidermis had changed but very little. There was a slight trace of alcohol present and a very bitter taste. The sugar content was high.

B. OCT. 19. Peaches treated as in part A but the air was not exhausted. DEC.18 Condition was the same as the condition of the peaches treated in part A.

C. OCT. 19. Peaches treated as in part A only no paraffin was put on them. Decomposition soon started. DEC. 18 the peaches were rotten and mushy, high in alcohol and there was water in the bottom of the jar, being formed during the changes within the peach.

D. OCT. 19. Treated as in part C. only the air was exhausted after sealing. DEC. 18 The peaches were similar to those in part C.

Thus the paraffin must have played at least an important part in the preservation of the tissues, it having undergone practically no change of skeleton in three months, when the peach was coated with paraffin.

It might be well to note here that in the case of all the peaches coated with solid paraffin (with a melting point above the room temperature), when cut around, the paraffin lifted off in halves, leaving the surface of the fruit clean.

A. OCT. 19. Peaches were immersed in liquid paraffin and placed in the ice box. NOV. 18 The entire surface of the peaches was brown. DEC. 18 The outer one fourth of the peaches was soft and mushy while the inner portion was hard and firm and slightly bleached. The bitter taste, noted above, was present. There was also alcohol noted.

B. OCT. 19. Peaches were placed in the ice box after being immersed in semi-solid paraffin with a melting point of about 34 degrees C. NOV. 1. Enough CO_2 had been given off by the peaches to force the paraffin and peach up out of the beaker. The whole paraffin and peach were pushed back into the beaker but of course the pressure was released for a time. DEC. 18 The peaches were very similar in condition to the ones treated with liquid paraffin.

C. OCT. 19 Peaches were immersed in solid paraffin and kept in the ice box. NOV. 10 The CO_2 given off had forced a small opening thru the bottom of the paraffin coat and had developed enough pressure to crack the bottom of the beaker. DEC. 18 The meat was firm and normal in color. There was a trace of alcohol and a high percent of sugar, accompanied by a bitter taste, the same bitter taste which was noted in all the peaches coated with paraffin.

3. - EFFECT OF WRAPPING EACH INDIVIDUAL PEACH.

It has long been maintained by most Pomologists that wrapping peaches with individual wrappers is not profitable as "ice scald" soon developes. Pears, also subject to "ice scald", in cold storage, are successfully wrapped and stored as are apples. In order to determine the effect of wrapping peaches, the following experiments were run.

Common apple wrappers were used to wrap some of the peaches which were kept with unwrapped peaches in the ice box. Some wrapped peaches were kept on the laboratory table with checks unwrapped. In no case was there any sign of "ice scald", tho the humidity was very high in the ice box at all times.

A. OCT. 19 Twelve peaches were wrapped and placed in the ice box. NOV. 9 Three showed signs of decomposition. NOV. 28 50% were wilted but still edible, yellow and dark around the seeds.

B. OCT. 19 Twelve unwrapped peaches were placed in the ice box. NOV. 9 50% were black and mushy. NOV. 16 All were rotten and soft. The wrapped fruit after 20 days, had kept 80% better than the unwrapped peaches.

C. OCT. 19 Twelve peaches were wrapped and left on the table at room temperature. OCT. 25 One was breaking down rapidly. OCT. 27 Three of the peaches had broken down. NOV. 1 All were "down", but not nearly as soft and rotten

as the unwrapped were under the same treatment.

D. OCT. 19 Twelve peaches were left on the table, unwrapped, as a check with the wrapped ones. OCT. 23 One was rotten and the others were soft and deep yellow. OCT. 27 All were soft and rotten. Again, the wrapped had held up about 80% better than the unwrapped.

From the above results, obtained with peaches wrapped and kept at room temperature and with peaches wrapped and kept in an ice box, in the same chamber with the ice where the moisture percent was very high, which is supposed to be one of the determining factors in the cause of "ice scald"; there is evidence that wrapping does not induce ice scald on cold storage peaches and that wrapping peaches prolongs the "holding up" of the fruit 80%.

4 - USE OF DISINFECTANTS ON RIPE PEACHES.

Disinfectants were next used. Cotton was placed in the bottoms of the fruit jars then moistened with the disinfectant, peaches put in and the jars sealed. A check was run by simply omitting a disinfectant and sealing the peaches in the jar. The cotton in one jar was moistened with a 5% solution of formalin and the cotton in another with a 95% sol. of alcohol. At the end of seven days the fruit was examined. All were badly decomposed but the untreated jar was the only one which did not have a vigorous growth of fungus on the fruit. The disinfectants had either not destroyed the fungi present

when sealed up or the cells of the epidermis of the fruits were made more permeable by the penitration of the disinfectants and were more readily attacked by the few fungi present.

5 - USE OF INVERTASE AND SACCHAROSE.

Thatcher having stated that no invertase was present in apples and that oxidases alone were responsible for the carbohydrate changes, it was decided to try invertase and saccharose to see if any change in the rate of decomposition would be caused by them.

A. OCT. 19 Peaches were immersed in a 50% normal solution of invertase (Browne "Handbook of Sugar Analysis", page 669). OCT. 23 A deep brown color had developed. NOV. 1 (Examined). The tissues stood out distinctly and the meat was bleached. No odor could be detected except the odor characteristic of yeast.

B. OCT. 19 Treated as in A except the invertase had been boiled to inactivate the enzyme. OCT. 26 Brown spots were appearing on the peaches. OCT. 27 The peaches were badly decomposed, the meat was bleached and tasted bitter.

C. OCT. 19 Invertase was injected into the peaches with a hypodermic syringe. OCT. 25 The peaches were all rotten. The regions immediately around where the invertase was injected, broke down first. No signs of bacterial or fungous growth were present. By injecting the invertase into the peach, the rate of decomposition was increased.

D. OCT. 19 Treatment was the same as in part A except that a

10% sol. of saccharose was used instead of invertase. The rate of giving off CO2 was slightly faster than when invertase was used as shown by the increase in the amount of bubbles given off. The rate of decomposition was also increased more than in the invertase solution. By OCT. 25 the peaches were all rotten.

E. Apples were injected with invertase. The invertase was injected into the apples in several places. Distilled water was injected into several apples in the same number of places and same amounts as was the invertase. After a week, the apples were cut open and examined. There was a marked difference between the condition of the apples injected with invertase and those injected with water. The regions around where the invertase was introduced were all brown in color and marked changes had begun to take place. The regions around where the water was introduced showed but little change, a slight drying of the cells had occured along the hole that the needle had made. In neither the apples injected with invertase nor with water had fungous or bacterial growth started.

6. - OXYGEN AS EFFECTING THE RATE OF DECOMPOSITION.

A. OCT. 23 Thirteen peaches were placed in a large desiccator and the air was replaced by O_2. The desiccator was left on the laboratory table. After two days the H_2SO_4 was removed from the desiccator as it was absorbing moisture and causing the peaches to wilt. The desiccator was again filled with O_2.

NOV. 9 Two peaches were wilted. NOV. 16 One peach was badly shriveled and all were a deep orange yellow. DEC. 18 The meat was the same shade of yellow as the epidermis in every case. There was a slight trace of alcohol and the meat had lost its flavor and was tasteless. The bitter taste present in the fruit coated with paraffin, was lacking. The seeds were normally bright and the tissues of the meat had apparently undergone no decomposition. Immediately upon exposure to the air, the epidermis and meat turned a deep brown.

The checks run with the peaches in the atmosphere of air broke down rapidly and were rotten in eight days.

B. OCT. 21 Peaches were placed in a fruit jar, air replaced by O2, then sealed and put in the ice box. Another jar of peaches was sealed up with an atmosphere of air instead of O2. DEC. 18. Peaches in the atmosphere of O2 had not decomposed as badly as those in the atmosphere of air, the taste was less bitter, a smaller percent of alcohol had been developed, and the color was not as dark.

C. OCT. 21 Two jars of peaches were treated as in B , then the jars were coated on the outside with paraffin and lamp black in order to keep the fruit in the dark. No difference could be found between these and the ones in the uncoated jars except that the epidermis and meat of the peaches in the dark jars were slightly lighter in color.

D. OCT. 21 A series, treated as in B. was left on the

laboratory table. The results were similar but the decomposition was much more rapid, due to the difference in temperature.

From the work with Oxygen gas, it is evident that enclosing in an atmosphere of O_2 does not increase the rate of the entire processes of decomposition but decreases it or at least some phase of it. This checking of the rate of decomposition can not be attributed solely to the presence of CO_2 evolved by the fruit as the fruits enclosed in an atmosphere of air broke down much sooner than those enclosed in the atmosphere of O_2.

7. - HYDROGEN PEROXIDE AS A SOURCE OF OXYGEN.

The most striking results were obtained by the use of a 3% solution of hydrogen peroxide and H_2O in proportion of 1 : 10 as a source of O_2.

OCT. 19 Peaches were placed in a fruit jar and the solution of hydrogen peroxide and water poured over them and the jar sealed. NOV. 19 No visible change in the peaches. NOV. 28 A small brown spot had appeared on the top peach where it was exposed to the air above the solution. When the top peach was examined, the margin line of the spot was as marked in the meat as it was on the surface of the peach. DEC. 18 The under peaches were normal in color, blush, freshness of appearance, size and shape. The meat was firm and the original color and texture had been retained. The seeds were normal in color also. The only changes were a trace of alcohol and a bitter taste.

8. - CONCLUSIONS.

1. Peaches immersed in oils as olive oil and vaseline, retained their firmness and structure much longer than when untreated, but the oils readily penitrated the meat and spoiled the quality of the peach.

2. Peaches coated with paraffin retained their color, firmness and structure as long as three months but in every case, alcohol had developed and there was a very undesirable bitter taste present. Solid paraffin did not adhere to the epidermis of the fruit but pealed off nicely. In all probability, the use of paraffin as a preservative for fresh peaches is made impossible by the presence of the bitter taste in peaches treated with paraffin. Solid paraffin with a high melting point gave results better than the lower melting paraffin.

3. The theory that wrapping peaches individually caused increase in "ice scald" and thus was impracticable, was disproven. Wrapping peaches from a commercial standpoint, would pay both for consumption on the market at picking time and for storage under normal conditions, regarding cost of labor and paper, etc. The rate of decomposition or "breaking down" was decreased 80% both with the peaches in the ice box and at room temperature. Thus, if used commercially, wrapping would increase the time of "holding up" of a ripe peach on the market from 4 - 5 days to 16 - 20 days.

4. No beneficial results were obtained by the use of disinfec-

tants, as the fungi developed readily on the fruits treated with the different disinfectants. This does not signify that disinfecting peaches before basketing would not pay commercially as, in the above work, the atmosphere around the peaches was saturated with the disinfectants and may have effected the structure of the cells of the epidermis and made them less resistant to the attack of bacteria and fungi.

5. ,Invertase and [illegible] increased the rate of change within the peach.

6. Oxygen supplied to peaches, both in the form of gas and in H_2O_2, decreased the rate of decomposition to a marked degree. The taste characteristic of the peaches coated with paraffin, was lacking tho alcohol and an undesirable taste developed when the peaches began to "break down" in the atmosphere of O_2.

7. Coating of peaches preserved the skeleton for a short period. Oxygen retards the rate of change but does not retard the "breaking down" of the structure of the peach as does coating, indicating that O_2 acts differently on the decomposition than does CO_2, **held in by the coating.**

8. The enzymatic changes within the peach are not entirely controllable by the treatment used but can be noticeably retarded by the use of an atmosphere of O_2 or a solution of H_2O_2.

9. The best results were obtained when H_2O_2 was used. By the use of H_2O_2 all phases of the processes of decomposition were controlled except the developement of a bitter taste.

II RESPIRATION OF APPLES IN A CURRENT OF OXYGEN.

From the work with peaches in an atmosphere of oxygen and in H_2O_2, it was found that there was a marked decrease in the rate of "breaking down", especially in the skeleton of the fruit. If the rate of decomposition is associated with the rate of respiration then the atmosphere of O_2 should either increase the rate of respiration and decomposition or decrease both, provided, that respiration depends upon the supply of O_2 from the air in the production of even part of the CO_2, given off during the process of respiration. By setting up a suitable apparatus where by O_2 could be passed over a known amount of fruit, in a regular flow and the CO_2 given off by the fruit carried with the escaping O_2 and weighed at regular intervals, the effect of O_2 on respiration could be determined accurately; thus the following experiments were conducted:

Apples were used because no other fruits as peaches, etc., could be obtained, due to the lateness of the season. The apparatus was designed and set up so that it may be used for various gases and different fruits and vegetables.

The apparatus was built so that a constant flow of gas could be passed thru the respiration chambers (containing the fruit) and nearly a constant temperature varying not more than ½°C during an entire "run", maintained at all times in the chamber. Figure I shows the entire apparatus and Figure II shows a cross section thru the apparatus.

Constant pressure was obtained in the gas bottles B & B' fig. I by means of the two constant level bottle A & A' fig. I. The in-flow of tap water into the constant level bottles being slightly greater than the out-flow into the gas bottles, there was a continual over flow into the drain tube and thereby the height of the water was always the same, giving constant pressure in the gas bottles. To avoid refilling at such short intervals, 40 l. bottles were used for the gas. From the large bottles, the gas passed into bottles C & C' Fig. I where CO2 was removed by bubbling thru sodium hydroxide solution. Next the gas was washed by bubbling thru water in the wash bottles L & L' fig. I.. From the wash bottle the gas passed into the respiration chambers thru individual tubes with glass stopcocks to regulate the rate of flow, the gas being introduced at the bottom of the chamber and taken off at the top. From the respiration chamber the gas passed thru water traps illustrated by F, fig. II. Next it was led thru a U tube of calcium chloride to remove traces of moisture before entering the potash bulbs where the CO2 was absorbed. The walls of the U tubes were greased with vaseline in order to prevent sealing up by the calcium chloride upon taking up moisture. The bulb was of the Liebig type and had a small calcium chloride tube ground on, in which was put, next to the bulb, crushed potash to absorb CO2 not taken up by the solution in the bulb, and lastly calcium chloride was placed in the bulb of the ground-on tube to catch any excess moisture that might

be swept thru the potash bulbs with the escaping air and oxygen. Glass wool was used where porous stoppers were needed, otherwise rubber stoppers were used. All connections were made with the ends of the glass tubing as close as possible, rubber tubing was wired and all connections, where possible, were sealed with Canada balsam. The stoppers were wired and sealed. The desiccators, used for respiration chambers, were held in place and prevented from rising in the water bath by means of the rods as shown in fig. II K. The constant temperature bath consisted of a galvanized tank 45 in. by 14 in. wide by 10 in. deep. A thermometer was suspended in the bath at each end of the tank. The water from the heating tank was introduced at the bottom of one end by means of a small rotary pump, driven by a motor. The water was taken off at the top and opposite end and returned to the heater by gravity. The motor furnished the power which ran the pump also propelled a small agitator in the heating tank which kept a more nearly uniform temperature there-in. At no time did the temperature of the bath vary more than ½ C during the entire "run" of a series. The temperature was controled by a mercury thermo-regulater which regulated the flow of gas to the burner under the heater, fig. I,N. Part of the supply of gas was piped directly to the burner, as indicated by the arrows in fig. I, the remainder passed thru the thermo-regulator. By the expansion or contraction of the column of mercury, this supply was cut down or increased, thus retarding

or increasing the heat given off by the burner under the heating tank.

The temperature was regulated to 32° C in the bath tank. The bubbles were regulated to approximately 40 per minute. At the start of each series, or run, the fruit was placed in the respiration chambers and allowed to remain there as the temperature of the bath came to 32 ° C. Air was forced thru all the respiration chambers for from 4 to 6 hours to sweep out all the excess CO2, then O2 was substituted for air in the three chambers with odd numbers (1, 3 and 5), the bulbs were connected and after regulating the rate of flow of the bubbles of air and O2, the bulbs were weighed and the weights recorded. The potash bulbs were removed and weighed at intervals of 12 hours as nearly as possible. The ground-on calcium chloride tubes were weighed with the bulbs. The bulbs were kept covered with cheese cloth to prevent dust from settling on them.

1 - CONSTANT CURRENT OF GAS

TABLE I. WILLOW TWIG APPLES (Constant flow of gas)

Willow twig apples, small and bruised, cold storage apples. The figures are on the basis of grams CO2 per hr. per 100 grams of fruit.

HOURS	OXYGEN		AIR	
STARTING	1.	3.	2.	4.
	(Grams per hr. per 100 gm. fruit)			
16 hrs.	.007[illegible]	.0078	.0062	.0062
25 "	.0048	.0046	.0034	.0034
40 "	.0046	.0038	.0053	.0053
48 "	.0030	.0037	.0045	.0044
63 "	.0057	.0054	.0049	.0049
72 "	.0020	.0010	.0016	.0016.

Numbers 5 and 6 were lost.

From the above table it is shown that the average rate of respiration per hour per. 100 grams of fruit is .00371 in the atmosphere of O2 and .00259 in the atmosphere of air. Showing an increase caused by the atmosphere of oxygen.

TABLE II. WINE SAP APPLES (Constant current of O2)

(Wine sap apples No. 88 in perfect condition)

TIME.	OXYGEN			AIR		
	(Grams per hr. per 100 gm. fruit.)					
	1.	.3.	5.	2.	4.	6.
7	.00240	.00659	.00484	.00365	.00424	.00940
25	.00288	.00162	.00391	.00329	.00332	.00378
32.5	.00315	.00399	.00371	.00298	.00510	.00249
48.5	.00409	.00184	.00486	.00275	.00360	.00333
55.5	.00932	.00758	.00334	.00331	.00348	.00373
62.5	.00465	.00516	.00225	.00306	.00328	.00434

With the wine saps in this series, the rate per gram per 100gm. fruit per hour averaged , .00410, .00457, and .00471 for the ones in oxygen and .00312, .00375 and .00360 for the air, showing again that O2 increases the rate of respiration of ripe apples.

2. - INTERMITTANT CURRENT OF GASES.

TABLE III. WINE SAP APPLES (Intermittant flow of gas)

Wine sap apples from the same box as those used in series II were used. In this series, the air and gas were passed thru in an almost continuous flow for one hour then the respiration chambers were closed up and allowed to stand for six hours when the bulbs were weighed and replaced, air and gas being run thru for another hour. This was repeated for ten periods with

the following results:

PERIOD.	OXYGEN. (Grams per hr. per 100 gm. fruit)			AIR.		
	1.	3.	5.	2.	4.	6.
1.	.00104	.00736	.00831	.00761	.00775	.00572
2.	.00781	.00593	.00612	.0059	.0053	.00431
3.	.00661	.00646	.0059	.0053	.00523	.00396
4.	.00534	.00586	.00527	.00321	.00524	.0036
5.	.00518	.00528	.00523	.00427	.0039	.00384
6.	.00525	.00521	.00536	.00351	.00354	.00336
7.	.00518	.00515	.00538	.00406	.00427	.00313
8.	.00197	.00230	.00231	.00173	.00184	.00138
9.	.00186	.00290	.00253	.00176	.00185	.00163

The averages run .00535, .00530, and .00534 for the ones in oxygen and .00446, .00450 and .00320 for those in the atmosphere of air. Showing that the rate of respiration again increased when in O2.

Altho the increase in the rate of respiration, as determined by the amount of CO2 given off, increased around 25% where the wine saps were in an atmosphere of O2, both constant flowing and intermittant, no increase in the rate of decomposition of the epidermis or flesh was noted, as compared with the ones run in the atmospheres of air.

Comparing the results of the above work with O2 with the work done with O2 in the first section of this report, it will be found that O2 increases the rate of respiration of fruits yet it prolongs the "holding up" period. This may be accounted for by the fact that the total gain in amount of CO2 given off in 5 months amounts to only 4.292 grams per 100 grams of fruit over the amount given off in the atmosphere of air.

As the rate of respiration decreases as the temperature is lowered, it will readily be seen that, at 32° F., the difference in the rate of respiration caused by forced ventilation or an excess of O2 being supplied would have no marked effect on decomposition of the fruit. The same conclusion will also hold good in force ventilation of refrigerator cars to prevent "ice scald".

While working out the details of the apparatus and perfecting it's running, pears were used in the respiration chambers. Due to the necessity of constantly making mechanical changes in the apparatus, no definite and concise figures can be given. On the whole the work with pears showed a marked increase in the amount of CO2 given off while in an atmosphere of O2 as checked with the ones in the atmosphere of air.

With the present apparatus, Fig. I, it will be possible to go into detail on the rate of respiration as effected by different gases, by temperature, by light, by wrapping, by coating with an insulator, etc., of various fruits and any stage of their developement.

3. - CONCLUSIONS.

1. In an atmosphere of O2 respiration is increased. Indicating that some of the O2 is used in the process of respiration.
2. No indications of increased decomposition were noted. This corresponds to the results obtained in the first part of the work.
3. The gain in the rate of respiration caused by an excess of

02 when forced ventilation of storage plants and refrigerator cars is used would be so small that, as a preventative of "ice scald", they could be used without effecting the fruit.

III COLOR AND ITS CORRELATION WITH THE ACIDITY OF AN APPLE.

In this brief work on the color of apples it was sought to determine whether or not there was a definite correlation between the intensity of color of the epidermis and the per cent of acidity of the meat. Is there a difference in the acidity of the meat of a light colored apple and a dark colored apple within the same variety which corresponds to the degree of coloring? And is there a difference in the acidity of the meat on the different sides of an individual apple which is colored on one side and not on the other? And, lastly, is there a color substance present in the epidermis which depends in part or altogether upon the per cent of acidity as to whether it is developed in the epidermis?

1. METHOD OF EXTRACTION OF COLOR.

The color was extracted by neutral alcohol. The apples were peeled as thin as possible and placed in a 50 c.c. measuring flask. Alcohol (95%) was added and the flasks marked and left on a 70° C. hot plate for twelve hours, then removed and the contents brought up to 50 c.c.

2. REDUCTION METHOD.

The reduction method used by Shibata, Nagia and Kishida, Jor. of Bio. Ch. 28, No.1.(1916) was used.

5 - 10 cc of the alcohol extract was acidified by

adding 5 - 10 drops of Conc. H Cl. A few cc of the acidified extract were placed in a test tube with a drop of mercury the size of a pea and a little magnesium powder, according to the method of Shibata,Nagai and Kishida. Reduction took place quickly with generation of free hydrogen and the production of a well defined pink color.

It was later found that the color was produced by H Cl so that all was needed was the addition of a few drops of con. H Cl to develope the color of the alcohol extract.

3. TEST FOR ACIDITY OF MEAT.

The acidity of the flesh was tested for by taking 10.cc. of the meat and placing it in a 50cc. measuring flask and a 95% solution of neutral alcohol. After remaining on the 70° hot plate for 12 hours the contents was brought up to 50 cc. and the acidity tested by titration with 10% N. KOH with phenolphthalein as an indicator.

The varieties tested for the acidity and color correlation and results are given in the table No. IV. The acidity is given based upon 1 as the acidity of the light apples in the ratio.

TABLE IV. CORRELATION OF COLOR AND ACIDITY.

Variety.	Ratio of the acidity. of acidity of meat.		Relative color
	(Light apples)	(Dark apples.)	
Unknown	1%	1.5%	Color same(Light pink)
Wine Sap	1	1.35	" " " "
Ben Davis	1	1.2	" " " "
Jonathan	1	1.1	" " " "
Minkler	1	1.	H Cl did not change the color.

No difference in the acidity of the light and dark sides of individual apples could be detected tho the color was present in both sides and gave a pink color with HCl of the same intensity with the individual apple.

4. - EFFECT OF DRYING UPON THE COLOR OF THE PEELING OF AN APPLE.

The peelings of several apples were dried in the drying oven described in the following pages. Peelings from light and dark apples were dried as were equal weights of the light and dark colored epidermis of individual apples. During the process of drying, the color of all of the samples darkened slightly. However, when dipped in a 1% sol. of salt just before drying, the color did not change when dried.

All of the varieties used in the acidity test were used except the Mirklers. In all of the samples the color corresponded to the color obtained in the same variety before drying.

5. - CONCLUSIONS.

1. There apparently is a definite correlation between the percent of acidity and the intensity of color developed in apples within a given variety.

2. No corresponding variation in the percent of acidity of the flesh, on the light and dark colored side of an apple, was found. However, with the limited amount of work done on this phase, no positive statement concerning this can be made.

3. The coloring substance of the apple is present in all parts of the epidermis but unevenly developed for some unknown reason.

The above work is a mere introduction into the possibilities of further work along similar lines. As cleft drafting, for instance, of a yellow variety upon a red variety will still give yellow colored fruit, it is evident that the color characteristics are present and function within the fruit to give it its color. Is there any correlation between the acidity of light and deep green colored foliage? Does there exist a correlation between the acidity of foliage and the acidity of the fruit within a variety, or between different varieties? And can the acidity of the foliage be taken as a criterion in determining the acidity of the fruit a given tree will bear, and would this tell to what extent the basic color, always present, will develop? These are only a few of the many problems suggested by the brief work reported on color of the epidermis of apples and it's correlation with acidity of the flesh.

IV. - EFFECTS OF DRYING ON APPLES.

The work on drying of apples was done to see if there was a change in the acid content, caused by the drying. Also, it was hoped that a method of drying, whereby the discoloring could be prevented without the bleaching with sulphur, might be found.

The apparatus used was a hand made dryer, devised and built for the occasion. The drying chamber consisted of an upright box 5 in. by 6 in. by 5 ft. long. The fruit was placed on twelve removable wire shelves set at equal distances in the box. One entire side of the box could be opened as shown in Fig. III. The air was heated by passing thru a pipe, heated by a gas burner, then the air entered at the bottom of the dryer, passed thru the shelves, and out at the top. The temperature could be regulated by the flame or by the amount of cold air passing into the heated pipe. The bottom temperature was kept at 85° C and the top at 35° C, when fruit was in the dryer. When filled with fruit, the temperature dropped between 20°- 25° C. All the material to be dried was first placed at the top of the dryer, then, as it dried, lowered to the bottom shelf, one shelf at a time. If placed on the lower shelves at the start, the fruit baked before drying.

The effect of drying upon the color of the apples was judged by comparison with the fresh fruit.

The acidity was determined as in the work previously discussed on the correlation of acidity with color in an apple.

1. - EFFECT OF DRYING IN LIGHT, DARK, AND SUNLIGHT UPON COLOR.

Wine sap apples were cored, peeled and sliced in circular slices as nearly the same thickness as possible. Samples of each apple were dried in the following ways; By placing in the sun out of doors; By artificially drying in the dark; And by artificially drying in the light. The color of the samples dried in the light and dark was the same, being slightly browned. The samples dried in the sunlight were very much browner than the other two. When first placed in the sunlight, the apples bleached and had all the appearance of sulphur treated samples, but the color soon changed, upon further drying, until a brown color had appeared. This changing of colors was doubtless due to some photochemical change, or change due to the presence of sunlight.

2. - EFFECT OF DRYING UPON ACIDITY.

Two samples of equal weight each of six Spitzenburg apples were taken, one sample was tested for the acidity, while fresh, and the other sample was dried and the acidity tested and recorded. In each case, the moisture percent of the dried apple was found.

The figures given below were determined on the basis of the acidity of the fresh samples. The acidity of the fresh

apple is taken as 1 in the table and the acidity of the corresponding dried samples, figured on this basis in the ratio.

TABLE 1 RELATIVE ACIDITY OF FRESH AND DRIED APPLE.

(Spitzenburg apples in bad, wilted condition.)

No. of apple sample.	Acidity of fresh flesh.	Acidity of dried flesh.
1	1.	.58
2	1.	.58
3	1.	.715
4	1.	.56
5	1.	.55
6	1.	.534

In this table, it is seen that dried to a moisture content of 9%, the total acidity of these Spitzenburg apples decreased almost one half. These results were not varified by further experimental work, thus, they warrant no conclusion, as to the exact effect of drying upon the acidity of apples in general.

3. - SOAKING FOR SOMETIME IN WATER BEFORE DRYING.

Apples were prepared as described above, then half the samples were soaked in water for two hours, before drying. Each shelf in the dryer contained the same number of soaked and untreated slices in order that the temperature would be the same on both the treated and untreated samples.

The untreated slices dried to a moisture content of 17.4% while the treated ones dried to 22% moisture. The treated apples dried out much thinner than did the untreated ones, indicating that the soaking, previous to drying, had caused some physiological change in the cell structure, so that when the

moisture was removed by evaporation, the cells collapsed or shrunk up more than the cells in the untreated did.

4. - DIPPED IN SOL. OF SALT AND SUGAR BEFORE DRYING.

Slices were dipped in a 1% sol. of salt, before drying, then dried with checks from the same apple, as in part three above. The color was slightly lighter in the ones dipped in the salt sol. before drying, than in the ones untreated. The salt did not taste, after drying.

Dipped in a 10% sol. of salt, before drying, the dried fruit retained the original color but tasted strongly of salt.

Dipping in a 1% saccharose solution had the same effects as dipping in a 1% sol. of salt.

Dipping in a 10% sol. of saccharose did not give quite as good results, in prevention of color, as did the 10% sol. of salt, there being a slight browning.

Powdered saccharose was sprinkled over the slices of apple just before placing in the drying oven. As a result, a brittle, dried candied apple was obtained. The original color was obtained and a very sweet taste was present.

Dried samples were taken and powdered in a mortar and placed in small bottles and the bottles sealed. The powder obtained from the untreated fruit was a shade yellower than the powder from the treated samples, but no difference in the shade

of coloring could be distinguished between the powders obtained from the samples treated in the various ways described above, before drying.

In each case, where the fruit was dipped in a sol. of salt or sugar, the moisture content was higher than in the check, as shown in the following table:

TABLE 2 EFFECT OF SUGAR AND SALT SOL. ON % MOISTURE.

Treatment.	% Moisture.
1% salt sol.	9.4 %
Check	8.9
10% salt sol.	6.2
Check	5.4
1% sugar sol.	5.4
Check	4.6
10% sugar sol.	3.0
Check	2.5
Coated with powdered saccharose	6.4
Check	4.2

The presence of the concentrated solutions on the surfaces of the fruit, while drying, must have inhibited the free passage of the moisture from the cells, thus holding the final moisture content higher than in the dried untreated fruit.

5. - MOISTURE ABSORBING POWER OF DRIED APPLES.

In order to find approximately how much moisture dried apples would absorb from the atmosphere, if left exposed, a weighing bottle was filled with a sample dried to 12% moisture. The top was left off of the bottle and care taken that no dust, or foreign matter might get in, the top being replaced while weighing. The following table shows the rate,

and amount of moisture taken up by this sample of dried wine sap apples:

TABLE 3 DRIED APPLES EXPOSED TO MOISTURE OF THE AIR.

Days.	Weight.	Gain in wt.	Total % gained.
1	3.8593 grams.		
2	3.9088	.0495 gm.	
3	3.9565	.0477	
4	3.9958	.0395	
5	4.0278	.0320	
6	4.0557	.0279	
7	4.0993	.0436	
8	4.1135	.0142	
9	4.1050	.0080 (Lost wt.)	
10	4.1048	.0002 " "	11%

Enough moisture had been taken from the air in ten days, at which time the absorption had stopped and the weight was fluctuating with the amount of moisture in the air, to bring the original moisture content (12%) up to 23% or an increase to 11% moisture. Commercially, apples are dried to a 27% moisture content, that being the standard.

It is certain that apples dried to a low moisture content can not be left exposed to the air for any length of time, as they will absorb enough moisture to spoil their keeping qualities. The capacity for taking up moisture of fruit treated with salt or sugar sol. before drying, was not determined.

6. - DRIED APPLES PLACED IN OIL PAPER BAGS.

The bags were made from the oil-paper used in packing cut flowers and was sealed by using a hot iron and paraffin.

Samples of the apples dried after dipping in the

salt and sugar sol., previously discussed, were sealed in the bags and left on the laboratory table. The oil paper did not keep out the moisture of the atmosphere and the material in the bags gradually took up moisture. After two weeks, they were no longer brittle, but leathery.

7. CONCLUSIONS ON DRYING WORK.

1. Artificial drying does not cause as much browning as the old sun-drying method.

2. In one specific case the per cent of acidity decreased during the process of drying. This result has not been verified by further investigation.

3. Soaking in water for two hours before drying had no effect upon the coloring of the apples brown while drying, but seemed to have affected the cell structure of the apple as shown by a decrease in volume as compared to the untreated check, dried with the treated apples. The soaked apples were also more difficult to dry as they retained the cell moisture longer than the fresh apples during the process of drying.

4. Salt or sugar solutions of various dilutions, preserve the original color while drying but they also increase the moisture retaining power of the apples. The use of sugar is doubtless more profitable from the commercial standpoint than salt as it counteracts the acidity of the fruit which would cause less sugar to be required upon cooking.

If the price of production is not prohibative, there

is no reason why there could not be dried apples put on the market in powdered form, as onions are, to be used as seasoning etc. Dried apples could be put on the market in sealed packages, as numerous breakfast cereals are at present, with the original color and flavor and in brittle, flake form, Sweetened properly during the process of drying, they would make a very desirable dish.

BIBLIOGRAPHY

DE SAUSSURE.. An. chin. phys. 1821)19-143-225 reported that green fruits acted like leaves in their usage of air. O2 disappeared in the daytime and carbon dioxide appeared, then at night the reverse occured, when exposed to sunlight the fruit gave off part of the O2 of the CO2 absorbed in the dark and used up all of the CO2 in the atmosphere surrounding them when enclosed in a vessel. He found that green fruit could remove as high as 7% CO2 from the air when artificially supplied with it.

FREMY Comp. rend. (1844) 19;784. Worked extensively on green fruits on the tree. He varnished the epidermis of the fruits, thus cutting off respiration. He found that growth stopped when varnished and then an analysis of the air in the fruits was made from which he thought that he had found a ferment which was the cause of the respiration of fruits.

LECHORTIER AND BELLAMY Comp. rend. (1869) 69; 356.466. sealed apples in jars for a long period then examined. They found much CO2 had been given off, alcohol had been formed and yeast cells were present in the parenchyma cells, thus showing that CO2 was given off in respiration and that alcohol was formed in the process of decomposition in enclosed jars.

SAINTPIERRE & MAGNIEN Ann.agro.-(1878) 4,161. showed that fruit gave off CO2 in light and dark both. That H2O was taken up or given off according to whether the fruit was in a wet or dry place. They maintained that the sugar and acid was

[illegible]

carried to the fruit thru the stem and the acid was later used in the process of respiration. That CO2 was given off as end product of respiration was established.

A. H. Benson Agr. Gaz. N. S. Wales 4,(1893) 11. drew the conclusions from his results or cold storage work, that peaches kept best at a temp. of 41.74° F. with high ventilation to prevent accumulation of CO2 which he held caused the rate of "breaking down" to increase. And that freestones could only be kept in cold storage for two weeks while clings could be kept for a month.

GERBER Annales des Sciences naturells; 4;1(1896)8. found a decrease of O2 and an increase in the amount of CO2 around unripe fruit after 24 hours of enclosure in a container. He enclosed some fruit on the tree but it failed to mature, thus he concluded that the O2 of the air was necessary for ripening of fruits on the tree. He tried experiments with various gases on fruit on the tree but got no results as he kept the fruit enclosed all the time and growth ceased.

L. LOISEAU Paris Librairie et Imp. Horticolas (1903) 31. Using a temperature of 0° C he found that 600 peaches kept in good shape for four weeks. After 35 - 40 days 10% had deteriorated. Two months, 75% had deteriorated and that wrapping did no good. Also he stated in his conclusions that storage peaches held up 7 days on the market while fresh ones only held up 3 days. The statements as to wrapping are disproven by the present work.

M. A. BLAKE & A. J. FARLEY N. J. Sta. Rept. 1911. tested the storage qualities of several varieties of peaches and found that early varieties broke down first and that the Elberta "stood up" best in storage. They attribute much of the failure to store peaches to lack of proper spraying to kill the fungi before storing instead of the natural processes of decomposition of ripe peaches.

BIGELOW U.S.B. of Ch. 94. found that storage had little effect upon the sugar, starch and acid content of apples. attributed ice scald to chemical changes within the apple or fruit and not to external conditions alone as accumulation of CO2 or high moisture content of air.

BIGELOW U.S.B. of Ch. 97. Studied four periods of the peach. After June drop; hard; market ripe; fully ripe. He found no starch in the first two periods. From stone hard to ripe the weight increased four times and the proportion of flesh to stone increased five times. From June drop to ripe the weight increased eight times. Sugar decreased and the acid increased. He gives the composition of peaches as; flesh 92.51%, stone 7.02% and kernel .69%.

G. H. POWELL. B.P.I. Bull. 40. reported that peaches kept in cold storage at 28° C kept perfectly for 2 weeks and "held up" on the market for 2 - 3 days after being taken from storage. When stored after ripe, peaches deteriorated faster than when put in hard ripe. Under higher temperature, deterio-

ration was more rapid. Wrapped pears kept better and ripened more slowly than unwrapped pears. Double wrappers gave better results than single wrappers with pears. No i[illegible] scald occured.

G. R. HILL. Jr. Cornell bull, 330 reported that the hardness of the peach is due to pectose and that "breaking down" is the changing of the pectose to pectin. He found that in an atmosphere of nitrogen hydrogen or CO2 green peaches, medium ripe peaches and ripe peaches lost their flavor and colored badly. That the softening of the ripe peaches was retarded by an atmosphere of CO2 and slightly retarded by N2.and H2. This respiration work was carried on with an apparatus somewhat similar to the one used in the experimental work given in this paper on the respiration of apples in an atmoshere of oxygen.

THATCHER Jr.Agr.Res. 5, (1915) 103. tried to seal fruit in a coating to prevent gaseous exchange but failed. He sealed apples in jars containing atmosphere of the following gases; oxygen, air, hydrogen, nitrogen, carbon dioxide and sulphur dioxide. He found that the CO2 checked the breaking down processes, which effect he attributed to the fact that CO2 is an end product of the chemical changes in the ripening processes of an apple and an excess of an end product retards the action of the enzyme causing the reaction in proportion to the increase of the end product. He could find no invertase present in an apple tho he found invert sugar present. All enzymatic

changes of the carbohydrates were attributed to oxidases only.

EDGAR RICHARDS Report Com. Agric. for 1886, Wash. D.C. reported work done on 17 varieties of apples before and after drying and that only slight chemical changes took place during drying.

C. A. BROWNE Penn. Dep't Agr. Bull 58.1899 published some work on the chemical composition of the apple and it's products. Copies of this work and the work of Richards were not obtainable by the writer.

The only other work relative to the chemical changes in fruits caused by drying, available, was the work on prunes done by G. W. Shaw of the Oregon Agr. Station and reported in bulletins 45(1886) and 61(1897). In these bulletins he deals mostly with the practical and commercial side of the drying of prunes and the analysis of fresh prunes. The only analysis of dried prunes given by him is preceded by a statement which emphasizes that it is only preliminary work and would be varified later. He draws no conclusions nor comparisons of the chemical changes caused by drying.

There is an abundance of literature available on dryers, evaporators and various phases of the mechanical side of drying and evaporation but practically no work has ever been reported on the chemical side of drying and evaporating.

SHIBATA, NAGAI AND KISHIDA; Jor. of Bio. Ch.XVIII, Dec. 1916. In this work on the presence of flavone in plants, they found that the mother substance of the red pigment(chromogen) was present in the white flowers of the Diervilla. Almost all kinds of white flowers contained flavone or flavonol glucosides, it being a common occurence in plant tissues also, localized chiefly in the epidermis and peripheral layer of the aerial part of the plant.

They concluded that flavone functioned as an absorbent for the ultra violet-rays of the sunlight, preventing them from injuring the living protoplasm and its biochemical agencies. They also thought that flavone played an important role in the processes of respiration. The formation of anthocyanin was supposed to be a simple biochemical reaction; a reduction of the already existing flavones.

In discussing flavone, they state that it depends upon sunlight for it's developement and that there is no appreciable loss of flavone by drying the specimen.

KEY TO FIGURES.

Figure I. Respiration Apparatus

A - Constant level bottles.
B - Pressure or gas bottles.
C - K OH bottles.
D - Water traps.
E - U tubes.
F - Potash bulbs.
G - Respiration chambers.
H - Platform
I - Support for U tubes.
J - Thermometers.
K - Agitator.
L - Wash bottles.
N - Regulator.
O - Belts from motor to pump and agitator.
U - Motor.
T - Pump.

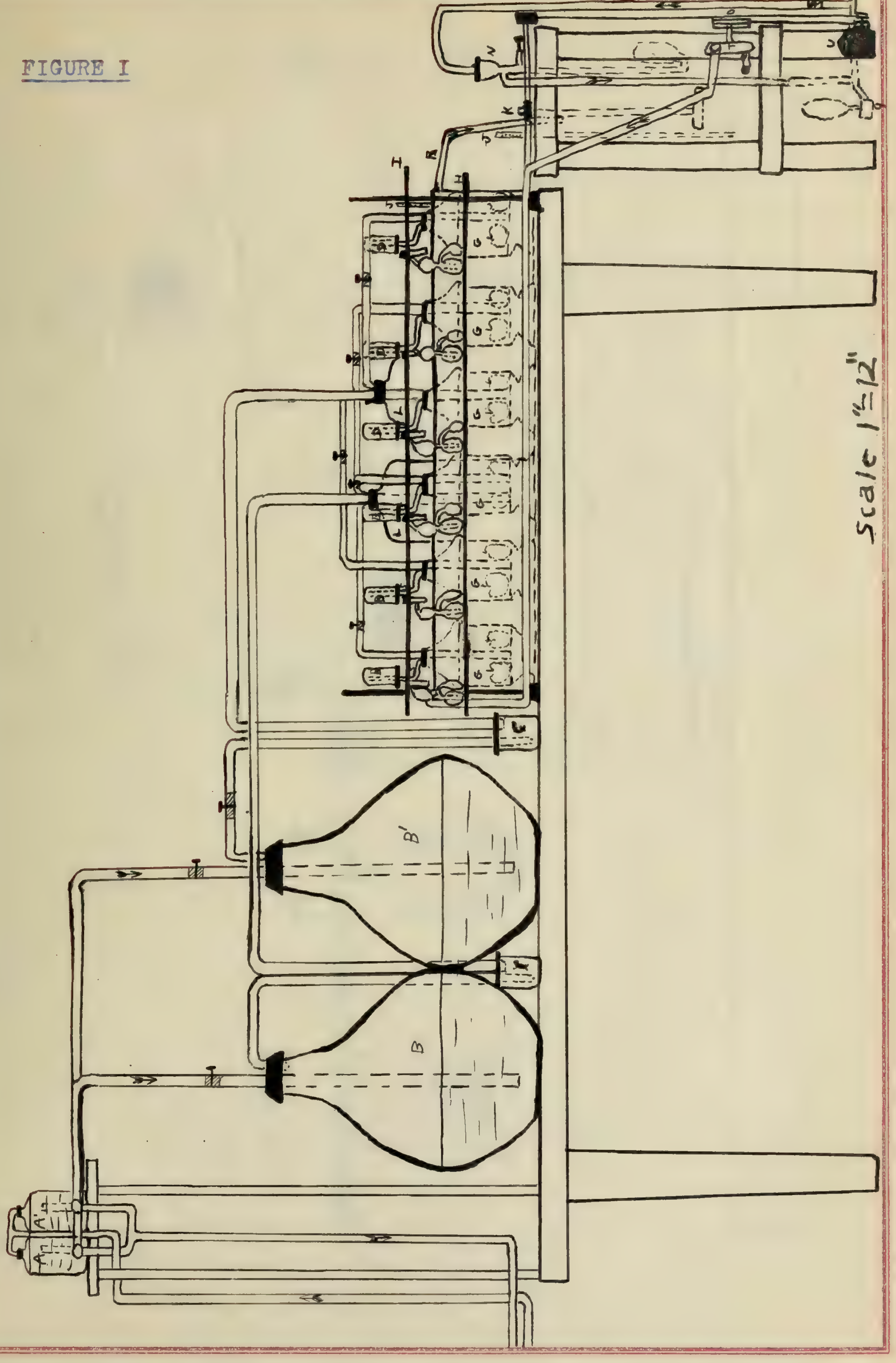
Figure II. Cross section of one section of respiration apparatus.

C - Potash bulbs.
D - U tubes.
E - Support for U tubes.
F - Water trap.
I - Respiration chamber (desiccator)
J - Fruit.
K - Rods for holding desiccator in place in hot water bath.
M - Wash Bottle.
N - Intake of gas from gas main.
O - Gas tubes leading to other two desiccators in this series.
P - Glass stop cock.

Figure III. Drying Apparatus.

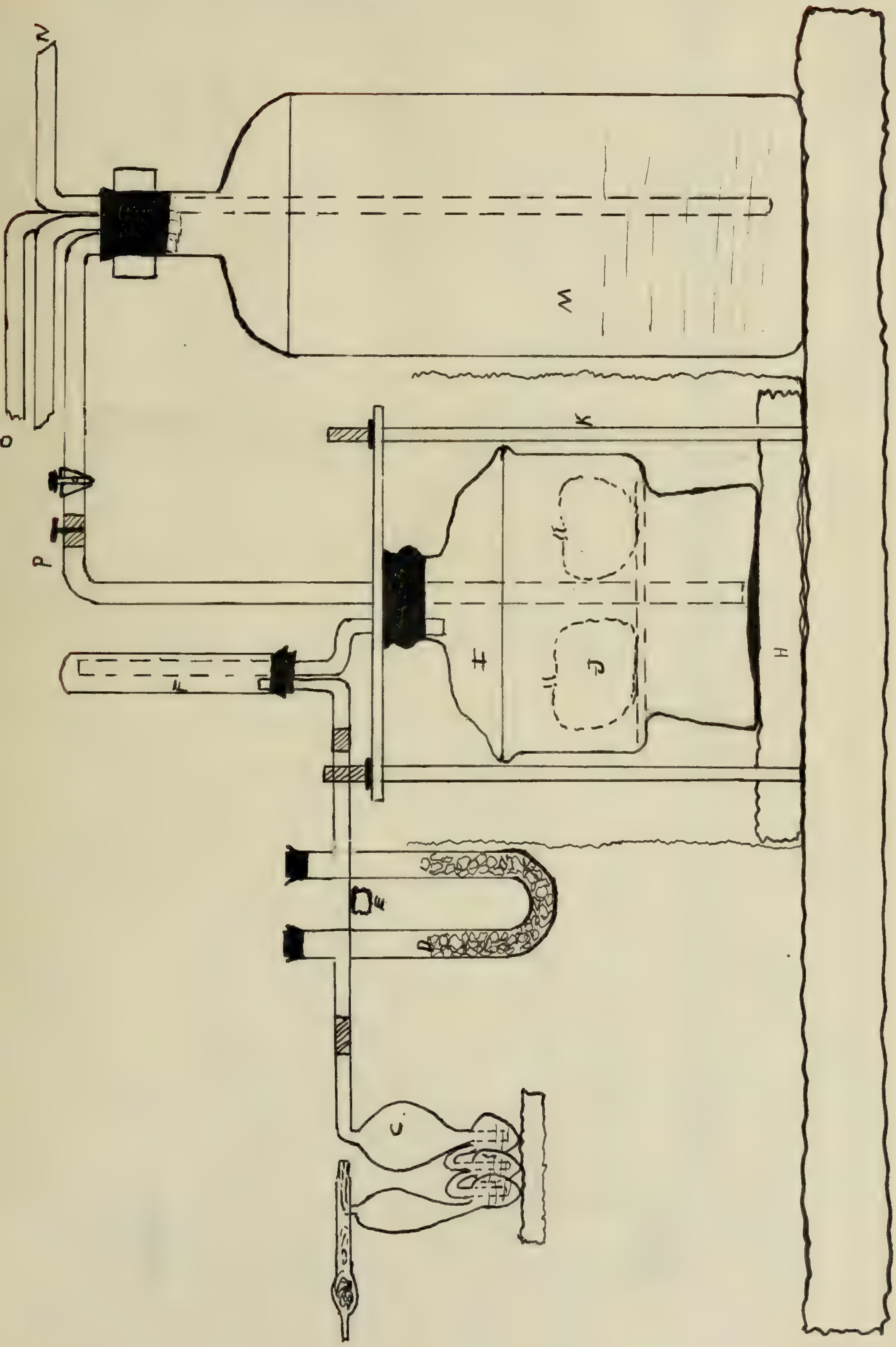
A - Outlet of air from drying chamber.
B - Drying chamber.
C - Iron pipe heated by burners.
D - Gas burners.
E - Air main.
F - Removable wire shelves.
G - Door to dryer.

FIGURE I



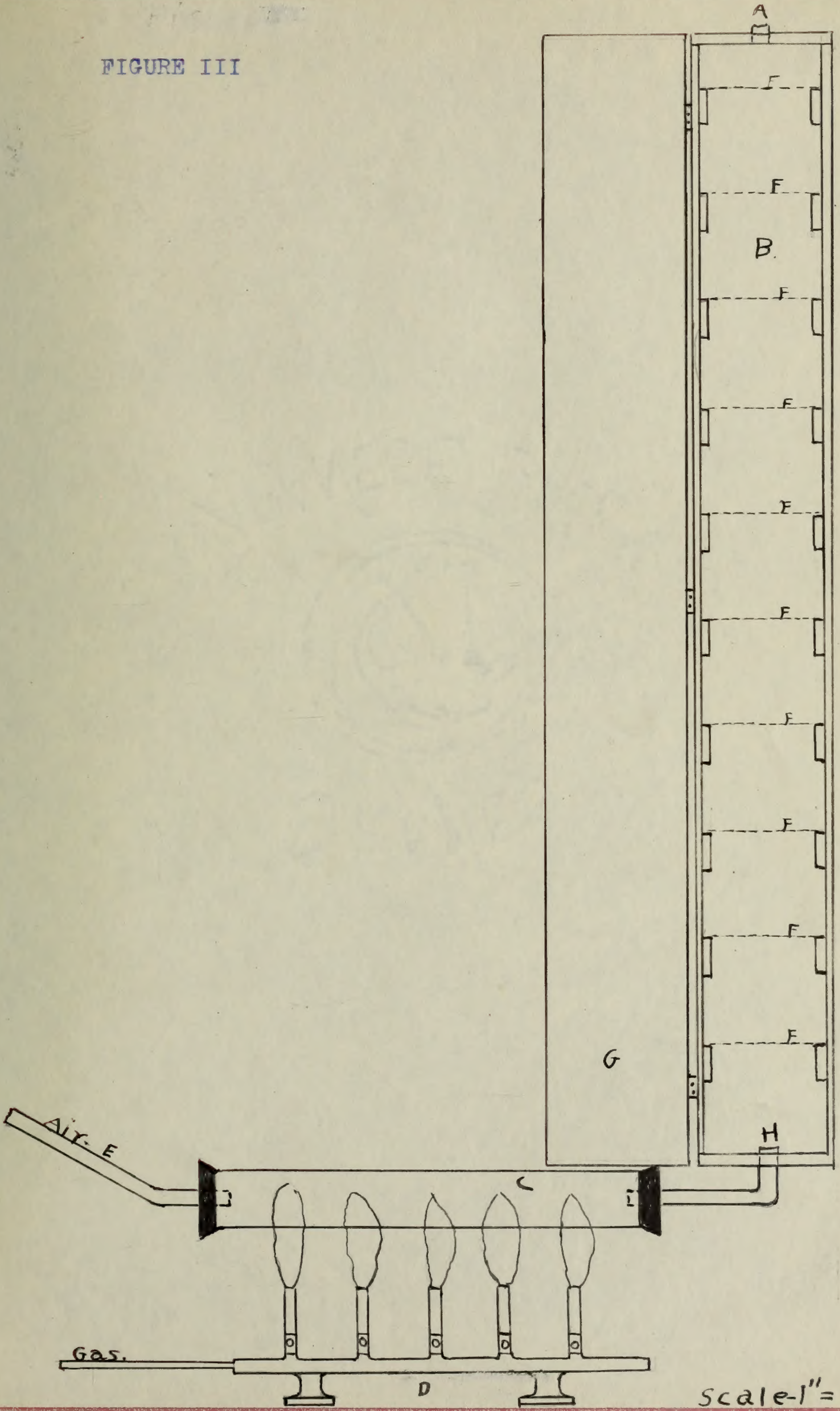
Scale 1"=12"

FIGURE II



Scale 1" = 4"

FIGURE III



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